OPTICAL RADIATION SENSOR DEVICE AND USE IN A RADIATION SOURCE MODULE

TECHNICAL FIELD

In one of its aspects, the present invention relates to an optical radiation sensor device. In another of its aspects, the present invention relates to a radiation source module comprising a novel optical radiation sensor device.

BACKGROUND ART

Optical radiation sensors are known and find widespread use in a number of applications. One of the principal applications of optical radiation sensors is in the field of ultraviolet radiation fluid disinfection systems.

It is known that the irradiation of water with ultraviolet light will disinfect the water by inactivation of microorganisms in the water, provided the irradiance and exposure duration are above a minimum "dose" level (often measured in units of microWatt seconds per square centimetre). Ultraviolet water disinfection units such as those commercially available from Trojan Technologies Inc. under the tradenames UV700 and UV8000, employ this principle to disinfect water for human consumption. Generally, water to be disinfected passes through a pressurized stainless steel cylinder which is flooded with ultraviolet radiation. Large scale municipal waste water treatment equipment such as that commercially available from Trojan Technologies Inc. under the trade-names UV3000 and UV4000, employ the same principal to disinfect waste water. Generally, the practical applications of these treatment systems relates to submersion of treatment module or system in an open channel wherein the wastewater is exposed to radiation as it flows past the lamps. For further discussion of fluid disinfection systems employing ultraviolet radiation, see any one of the following:

United States Patent 4,482,809,
United States Patent 4,872,980,
United States Patent 5,006,244,

United States Patent 5,418,370,
United States Patent 5,539,210, and
United States Patent 5,590,390.

In many applications, it is desirable to monitor the level of ultraviolet radiation present within the water under treatment. In this way, it is possible to assess, on a continuous or semi-continuous basis, the level of ultraviolet radiation, and thus the overall effectiveness and efficiency of the disinfection process.

It is known in the art to monitor the ultraviolet radiation level by deploying one or more passive sensor devices near the operating lamps in specific locations and orientations which are remote from the operating lamps. These passive sensor devices may be photodiodes, photoresistors or other devices that respond to the impingent of the particular radiation wavelength or range of radiation wavelengths of interest by producing a repeatable signal level (in volts or amperes) on output leads.

Conventional optical radiation sensors, by design or orientation, normally sense the output of only one lamp, typically one lamp which is adjacent to the sensor. If it is desirable to sense the radiation output of a number of lamps, it is possible to use an optical radiation sensor for each lamp. A problem with this approach is that the use of multiple sensors introduces uncertainties since there can be no assurance that the sensors are identical. Specifically, vagaries in sensor materials can lead to vagaries in the signals which are sent by the sensors leading to a potential for false information being conveyed to the user of the system.

Accordingly, it would be desirable to have a radiation source module comprising an optical sensor which could be used to detect and convey information about radiation from a number of radiation sources thereby obviating the need to use multiple optical radiation sensors.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a novel optical radiation sensor which obviates or mitigates at least one of the above-mentioned disadvantages of the prior art.

It is another object of the present invention to provide a novel radiation source module which obviates or mitigates at least one of the above-mentioned disadvantages of the prior art.

Accordingly, in one of its aspects, the present invention provides, an optical radiation sensor device for detecting radiation in a field comprising:

a radiation collector for receiving radiation from a predefined arc around the collector within the field and redirecting the received radiation along a predefined pathway; and

a sensor element capable of detecting and responding to incident radiation along the pathway.

In another of its aspects, the present invention provides a radiation source assembly comprising a protective sleeve containing: (i) at least one radiation source, and (ii) a radiation sensor device for detecting radiation in a field, the sensor device comprising: a radiation collector for receiving radiation from a predefined arc around the collector within the field and redirecting the received radiation along a predefined pathway; and a sensor element capable of detecting and responding to incident radiation along the pathway.

In yet another of its aspects the present invention provides a radiation source module comprising a frame having a first support member; at least one radiation source assembly extending from and in engagement (preferably sealing engagement) with a first support member, the at least one radiation source assembly comprising at least one radiation source and a radiation sensor device for detecting radiation in a field, the device comprising: a radiation collector for receiving radiation from a predefined arc around the collector within the field and redirecting the received radiation along a predefined pathway; and a sensor element capable of detecting and responding to incident radiation along the pathway.

In another of its aspects, the present invention provides a fluid treatment system comprising an array of radiation sources for generating a field of radiation, the array of radiation sources further comprising a radiation sensor device for detecting radiation in the field of radiation, the sensor device comprising: a radiation collector for receiving radiation from a predefined arc around the collector within the field of radiation and redirecting the received radiation along a predefined pathway; and a sensor element capable of detecting and responding to incident radiation along the pathway.

Thus, the present inventors have discovered an optical radiation sensor having a radiation collector for incident radiation which can collect and redirect, as appropriate, incident radiation from a number of radiation sources to a single sensor and convey information about the radiation output of the plurality of radiation sources via a single radiation sensor. Preferably, this is achieved by having a radiation collector at an end of the radiation sensor which has a concave surface or a convex surface. Preferably, if a concave surface is used, the surface additionally comprises a reflective coating to enhance collection of radiation.

As used throughout this specification, the term "concave surface" is intended to mean a surface of a radiation collector which extends into the body of the collector (generally, the surface would protrude proximally with respect to the sensor element). Further, as used throughout this specification, the term "convex surface" is intended to mean a surface of the radiation collector which protrudes out of the collector body (generally, the surface would protrude distally with respect to the sensor element).

Thus, the radiation collector in the present optical radiation source device serves to gather or collect radiation from a predefined arc around the collector and redirect this radiation toward the radiation sensor. When the collector is in the form of a concave surface, a mirror effect may be used to reflect the radiation toward the sensor whereas when the collector is in the form of a convex surface, the incident radiation is refracted, internally reflected or diffused toward the radiation sensor. Preferably, the predefined arc around the collector is a 360° arc although, in some cases, it may be useful and even advantageous to have a single arc of less than 360° or a number of arcs less than 360°C contained within the

field of radiation. Those of skill in art will recognize that the it is not necessary for the predefined arc to be coterminous with the arc of the field of radiation at the plane of radiation incidence.

In a further preferred embodiment, the sensor device is oriented with respect to an elongate radiation source such that the predefined arc referred to above is in a plane which is substantially transverse to the longitudinal axis of the radiation source.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described with reference to the accompanying drawings, wherein like numerals denote like elements and in which:

Figure 1 illustrates a schematic of an array of radiation source assemblies in partial section including a radiation source assembly in accordance with the present invention;

Figure 2 illustrates a schematic of a cross-sectional view of an array of radiation source assemblies including a radiation source assembly in accordance with the present invention; and

Figure 3a-3h each illustrate an end view and side elevation view of a number of embodiments of radiation collectors useful in the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

With reference to Figure 1, there is illustrated a trio of radiation source assemblies 120,130,140. These radiation source assemblies could be contained in a radiation source module such as the ones described in the United States patents referred to hereinabove and/or in the radiation source module described in copending United States patent application S.N. 09/258,142 (Traubenberg et al.).

Radiation source assembly 120 comprises a radiation source 122 disposed within a protective sleeve 124.

Radiation source assembly 130 comprises a radiation source 132 disposed within a protective sleeve 134.

Radiation source assembly 140 comprises a radiation source 142 disposed within a protective sleeve 144.

As will be apparent to those of skill in the art, radiation source assemblies 120 and 140 are similar in construction.

Radiation source assembly 130 also comprises an optical radiation sensor 150. Optical radiation sensor 150 comprises a radiation collector 152 connected to a sensor photo-diode 154. Sensor photo-diode 154 is connected to a housing 156. Emanating out of housing 156 is an electrical cable 158. The sensor photo-diode or other sensor material may be chosen from conventional sensors materials. For example, a suitable sensor material is commercially available from UDT Sensors Inc. (Hawthorne, California)..

Disposed between optical radiation sensor 150 and radiation source 132 is a radiation shield 180. Radiation shield 180 serves to block radiation from radiation source 132 being detected by radiation sensor 150.

Radiation collector 152 comprises a concave surface 153. Concave surface 153 has disposed thereon a specularly or diffuse reflective material 156 (e.g., a Teflon™ coating) which serves to reflect incident radiation impinging thereon toward sensor photo-diode 154. Since radiation collector 152 is a solid body, it is preferred that it be constructed from a radiation transparent material (e.g., quartz and the like).

With reference to Figure 2, there is illustrated, in schematic an array of radiation source assemblies 120 and 140 surrounding radiation source assembly 130. As illustrated, a portion of the radiation emanating from radiation source assemblies 120,140 will be that depicted by the dashed arrows in Figure 2. This radiation will impinge on reflective material 155 on concave surface 153 and be reflected toward sensor photo-diode 154. In this manner, optical radiation sensor 150 may be viewed as a "360° sensor" in that it can receive and detect radiation from a substantially 360° plane (2-dimensional) or conoid (3-dimensional) around the collector. This constitutes a significant advance in the art in that the use of multiple sensors can be avoided.

With reference to Figure 3a, there is illustrated an enlarged view of radiation collector 152 shown in Figure 1. Again, it is useful to coat the concave

surface with a reflective material that will reflect incident radiation toward the photo-diode. As illustrated radiation collector 152 in Figure 3a may be constructed from solid quartz and is attached directly to the photo-diode (154).

With reference to Figures 3b-3h, there are illustrated a number of alternate embodiments for radiation collector 152 illustrated in Figures 1 and 3a.

Figure 3b is a modification of the embodiment of Figure 3a wherein the radiation collection and reflection element is not directly connected to the photo-diode. In other words, in the embodiment illustrated in Figure 3b, the radiation collection and reflection element is remote from the photo-diode. Otherwise, the operation of the radiation collector in Figure 3b operates in the same manner as that described hereinabove for the radiation collector of Figures 1-2.

The radiation collector illustrated in Figures 3c-3g share the feature of having a collector with a convex surface. In this instance, a reflective coating is not required. Rather, incident radiation on the convex surface of the collector is redirected to the photo-diode by refraction, reflection and/or both (i.e., a "prism effect"). In essence, Figures 3c-3g illustrate that the particular shape of the convex surface of the radiation collectors not particularly restricted provided that the appropriate refraction or "prism effect" can be achieved to redirect incident radiation toward the photo-diode. Generally, if the cross-section of the radiation collector parallel to a plane of incident radiation is circular (e.g., as shown in Figures 3a-3e), the radiation collector will have a radiation collection arc of substantially 360°. Generally, if the cross-section of the radiation collector parallel to a plane of incident radiation is polygonal (e.g., pentagonal as shown in Figure 3f, octagonal as shown in Figure 3g, triangular as shown in Figure 3h and the like), the radiation collector will have one or more radiation collection arcs of less than 360°.

While the present invention has been described with reference to preferred and specifically illustrated embodiments, it will of course be understood by those of skill in the arts that various modifications to these preferred and illustrated embodiments may be made without the parting from the spirit and scope of the invention. For example, while the present invention has been illustrated with reference to radiation source modules similar in general design to those taught in

United States Patents 4,872,980 and 5,006,244, it is possible to employ the present radiation source assembly in a module such as the one illustrated in United States Patents 5,418,370 , 5,539,210 and 5,590,390 - i.e., in a module having a single support for one or more elongate source assemblies extending therefrom. Further, it is possible to em ploy the present radiation source assembly in a fluid treatment device such as those commercially available from Trojan Technologies Inc. under the tradenames UV700 and UV8000. Still further, while, in the embodiments illustrated and described above, the optical sensor is disposed at the end of the protective sleeve opposite the end where electrical connections for the lamp are located, it possible to locate the optical radiation sensor at the same end as the electrical connections for the lamp thereby allowing for use of the protective sleeve having one closed end. Still further, it is possible to utilize an optical radiation source sensor disposed between two radiation sources, all of which are disposed within a protective sleeve. Still further it is possible to modify radiation collector 152 in Figures 1 and 3a so that the reflective coating is in a number of bands thereby modifying the collector to have one or more radiation collection arcs less than 360°. Other modifications which do not depart from the spirit and scope of the present invention will be apparent to those of skill in the art.